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Klinglmair, Manfred; Scheutz, Charlotte; Astrup, Thomas Fruergaard

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# Phosphorus in Denmark: national and regional anthropogenic flows

Manfred Klinglmair, Charlotte Scheutz, Thomas Astrup



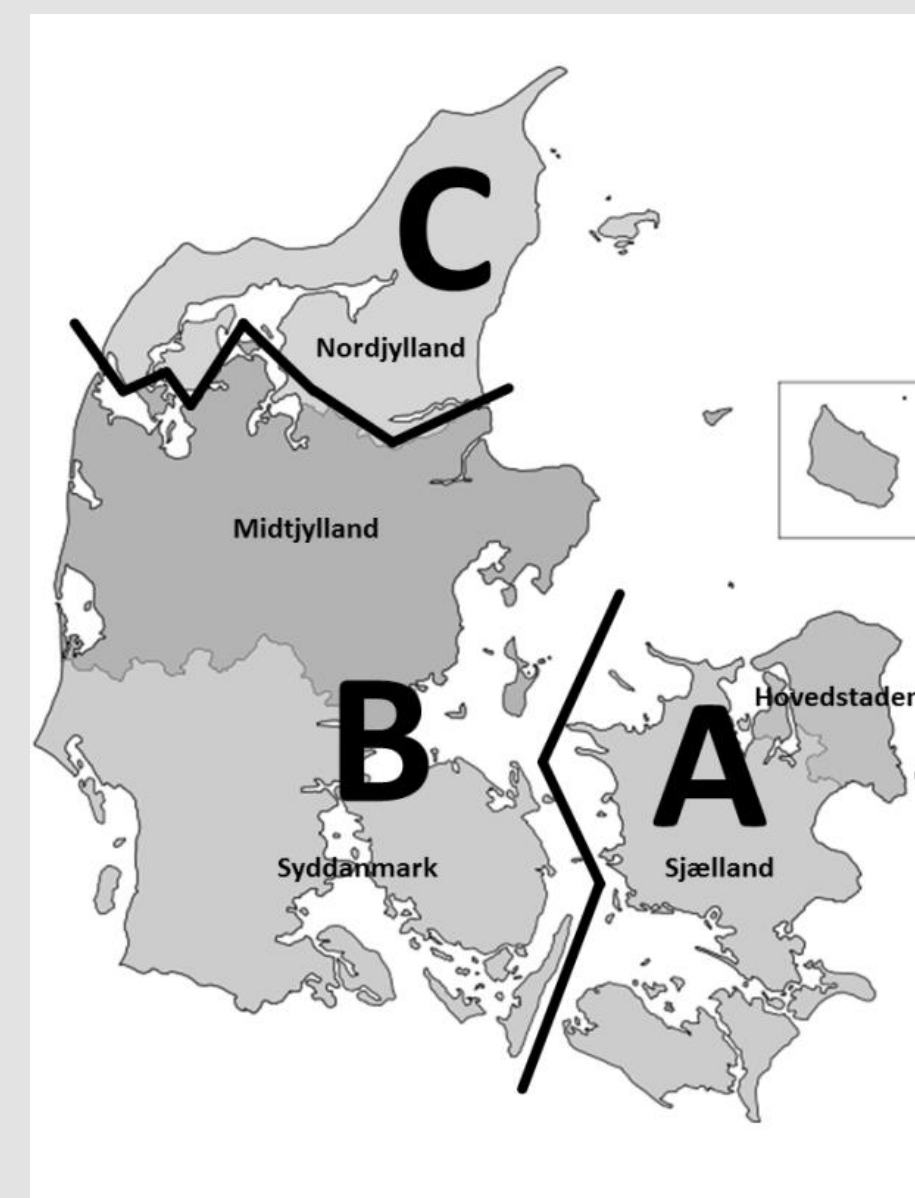
## Background & aim

Phosphorus (P), an essential plant nutrient mined from the earth's crust as phosphate rock, is a crucial resource for future food security, as there is no substitute for P in agricultural production. Global "peak phosphorus" looms in the future, although the likeliness of this is debatable due to new deposits becoming economically accessible with time. From a European perspective, P scarcity is a potential geopolitical and strategic threat, as Europe's own rock phosphate reserves are negligible. The global nature of modern food production has led to the P cycle being "broken" on a global scale; on a more local scale, P is lost through inefficient use in agriculture or is dissipated in the form of waste, animal manure applied in excess of plant demand, other organic waste, and waste water, which will be lost if not recycled appropriately.

We aimed to: **i)** to assess anthropogenic P flows for Denmark, both at the scale of the entire country and its economy, and on a smaller, regional level, the latter dividing into regions dominated by either crop production or animal husbandry, leading to imbalances in P loads, in order to identify flows and regions holding potential for increased recycling of P, **ii)** to identify the main barriers to more efficient recovery and reuse of P, and quantify future potentials for substituting mineral P fertilizers and more efficient utilization of P resources in Denmark.

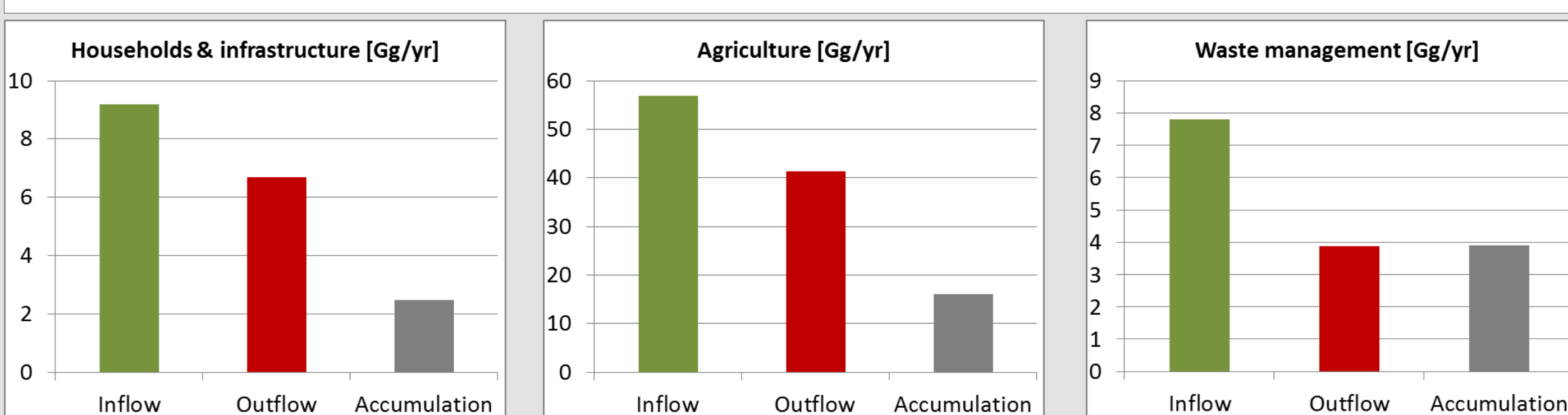
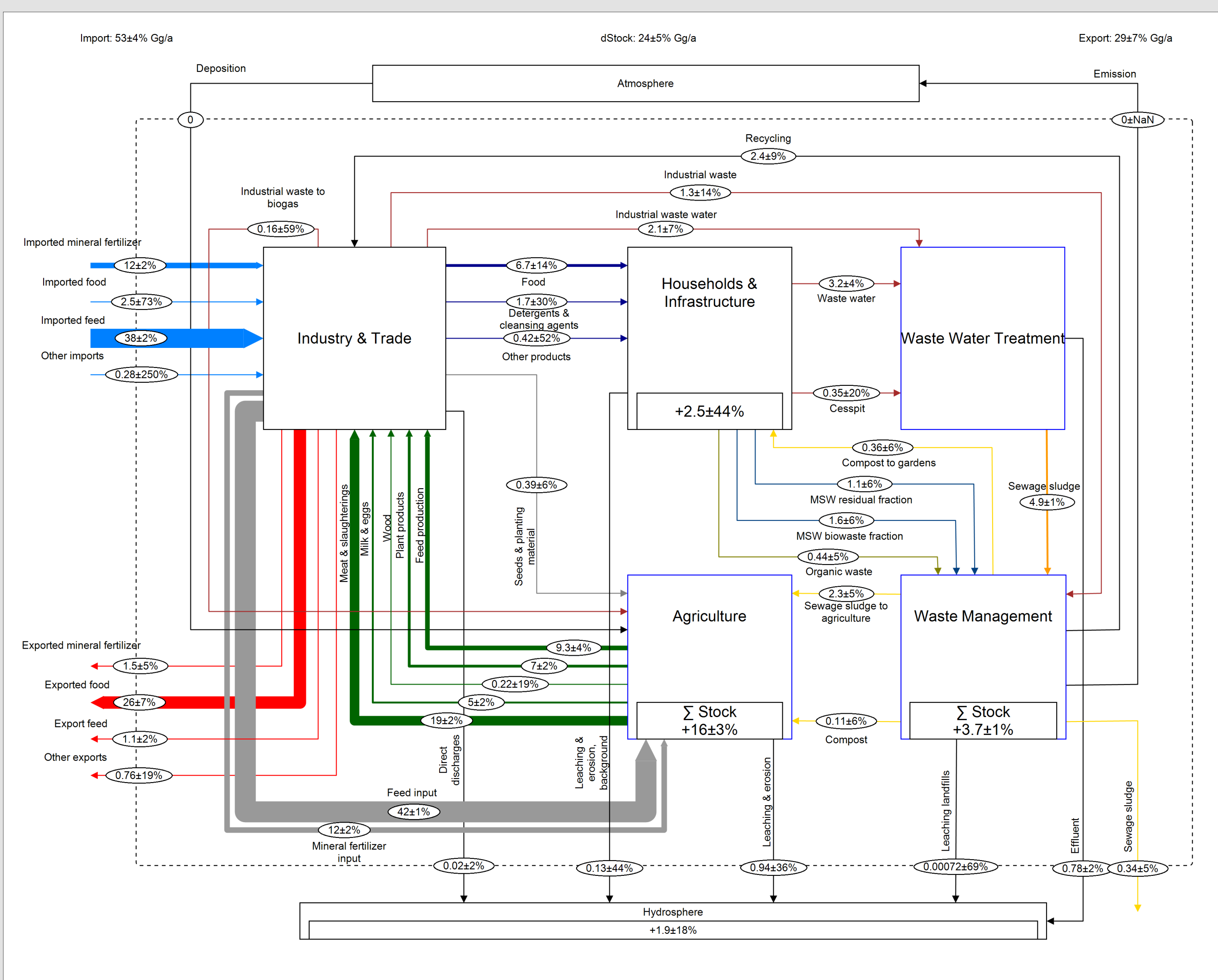
## Methodology

We use the approach of Material Flow Analysis (MFA), in which flows and stocks of a substance or material are quantified within a spatial and temporal system boundary, establishing a material balance of the system in question. Flows, stocks, and stock changes within the system are quantified. The STAN version 2.0 MFA software was used for visualization, consideration of uncertainties and data reconciliation.



For a meaningful assessment, a regional perspective on agriculture and waste management is useful. We divide the MFA system along administrative borders, which also corresponded with differences in agricultural practice: Sjælland and region Hovedstaden (including the island of Bornholm) in the east of the country, here denoted region **A**; Syddanmark and Midtjylland, region **B**; and Nordjylland, denoted region **C**.

## Results



As the figure shows, the Danish P household is dominated by animal husbandry. The **largest P inflow** occurs via **feedstuff import** to support intensive animal production. The amount of P **re-used** within the system, from compost, fish/meat/bone meal, and sewage sludge, amounts to only approximately 4.8 Gg/yr, or about 9% of the annual P inflow. Manure excretion from Danish animal husbandry is a main contributor to the build-up of P stocks in agriculture. High rates of P accumulation correspond to high numbers of farm animals and hence manure production; fertilizer imports for crop production, due to the removal of P with crops harvested from the field, play a lesser role.

The largest untapped potential for phosphorus recovery is associated with human habitation: biowaste non collected separately (1,6 Gg/yr), and a more complete re-use of P from sewage sludge (presently 2,3 out of 4,9 Gg/yr).

## Conclusions

Current potential amounts of recoverable phosphorus cannot be expected to change the reliance on mineral phosphorus. There is limited immediate potential in the waste management system to substitute mineral fertilizer imports. The relevant flows are generally more than one order of magnitude smaller than P flows in fertilizer and manure.

While the amount of organic waste, as compost, presently used on agricultural land is negligible at 1% of P in fertilizer imports, the **biowaste** fraction of household waste is not currently collected separately and hence unused by agriculture. This unused P source holds a country-wide average **potential of approximately 13%** of the P in mineral fertilizers applied. At present, P from these sources constitutes an unused potential. Nutrient availability from **manure** holds the most conspicuous potential for fertilizer substitution, although it is currently not recycled in the most effective way. This is a **transport or distribution problem** as transport distances for farmyard manure are limited to the local scale, and availability of manure is highest where there is least demand, i.e. areas dominated by animal husbandry as opposed to crop farming.

Conversely, Sjælland and the capital region have the highest ratio of crop production in agriculture, as well as a slight deficit in the overall soil P budget and the highest use of mineral fertilizer of the regions we studied. This coincides with the region being the location of the country's **largest urban agglomeration**, resulting in the **largest P flow in sewage sludge and other P-rich wastes** of the three regions. A more extensive recovery and use of P from sewage sludge, therefore, appears to be the most meaningful option for more efficient P management in this region.

## Contact



www.IRMAR.dk  
www.env.dtu.dk

**Contact:**  
Manfred Klinglmair  
Miljøvej, Building 113  
2800 Kongens Lyngby  
IRMAR@env.dtu.dk

mank@env.dtu.dk